Novel High Performance Piezoelectric Composites for Actuators

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We have developed a coupled length scale, coupled method approach that can be used to realistically simulate general composite materials for time scales approaching one cycle of a typical piezoelectric actuator. We applied this method to search for novel actuator materials using an efficient materials search algorithm. We found that composites of perovskite ferroelectrics, such as PZT, and certain soft molecular solids show great potential. In particular, although the responses are nonlinear and frequency dependent, extremely large actuation forces are possible relative to the volume of active material. Furthermore, very high efficiencies seem to be possible. We expect that the nonlinear response of the material can be corrected by proper transducer design and appropriate electronic drive circuitry. In order to verify this concept, a sample, corresponding to the most favorable case identified by our calculations – 40-60 PZT/semtex, was made and tested in a standard rig by Dr. B.B. Gun (deceased). Initial results confirm our calculations, and remarkably yield a piezoelectric efficiency greater than unity (actually $\sim 2 \times 10^5$). Unfortunately, multiple actuation cycle testing could not be completed due to sample degradation. We are presently parallelizing our codes to permit longer time simulations on high performance computers. This will allow us to simulate multiple actuation cycles in order to understand the reasons for the sample degradation and thereby identify ways of stabilizing the devices.

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